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ON PRONOUNCED ATMOSPHERIC MODULATION OF THE GEOMAGNETIC DAILY VARIATION

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ABSTRACT

Seasonal asymmetry in the daily variation of the geomagnetic declination has been studied for the observatories of Honolulu, Hawaii, Tucson, Ariz., and San Juan, Puerto Rico, for an 11-yr. period. Behavior unsymmetrical with respect to the seasonal change of solar radiation is conspicuous and suggests the action of an atmospheric factor, probably the large-scale air circulation in the lower ionosphere. There appears to be a correspondence in time between two evident seasonal changes in the daily variation of the declination and in the large-scale air circulation in the upper stratosphere, as at the 10-mb. surface (approximately 30 km.).¹ The value of a comparative study of the form of the geomagnetic daily variation and the daily patterns of large-scale air circulation in the upper stratosphere is emphasized. For studies of this kind it is urged that a greatly condensed daily numerical index of the charts of the upper stratosphere (analogous to the indices that exist for geomagnetic and solar data) would be of much help.

1. INTRODUCTION

Asymmetry of the daily variation of the earth's magnetic field with respect to the solstices, that is, asymmetry with respect to the intensity of ionizing solar radiation in the lower ionosphere, is indicative of the operation of a terrestrial factor. In the daily variation of the field this factor is probably some physical characteristic of the lower ionosphere where the electric currents flow that produce the daily variation. The most probable factor is seasonally (and daily) changing large-scale air circulation in the lower ionosphere through its effects on ionization equilibria and through its shaping of the resultant solar-produced daily periodic winds there that lead by dynamo action to the ionospheric electric currents which produce the daily variation of the field.

In certain cases, at least, the daily variation exhibits this

asymmetry in a striking way and suggests that the continuous daily records of the earth's magnetic field from the many magnetic observatories of the world contain valuable information concerning meteorological conditions in the lower ionosphere. I believe this circumstance has not received the attention it deserves.

In three recent papers I have illustrated this seasonal asymmetry as it occurs in the daily variation of the horizontal component of the field at the observatories of Honolulu, Hawaii, Tucson, Ariz., and San Juan, Puerto Rico, respectively [2, 3, 4]. In the present paper such asymmetry is illustrated for another component of the field, the declination, for these three observatories in a simpler but less detailed manner than that used in the papers on the horizontal component.

In 1950 Wulf and Hodge [5] pointed out, in a paper on the relation of the daily geomagnetic variation to large-scale atmospheric circulation, that the range of the daily variation of the declination at Tucson undergoes a re-

¹ The 10-mb. surface lies in about the middle of the stratosphere, and the expression "upper stratosphere" will be used here to denote the middle and high stratosphere.

markedly asymmetric change with respect to the solstices, that is, with respect to the sun's noon zenith angle throughout the year, and illustrated this, in figure 8 of that paper, for the six years 1940-1945. The late maximum of the range in August, considerably after the maximum of solar radiation in the lower ionosphere, shown by the average for these years, was well borne out by the data for the individual years. A tendency for a small maximum in January was also present. The intensity of solar radiation in the lower ionosphere (barring variable absorptive power above this level) should be symmetrical with respect to the solstices, and it was felt that these data indicated a pronounced influence of atmospheric circulation on the daily variation of the field.

2. PRESENTATION OF DATA

It is the purpose of the present article to extend this earlier work on the geomagnetic declination to 11 other years and to two other observatories, Honolulu and San Juan, to show how pronounced this apparently atmospheric influence is, and to suggest a method for comparing, in the results for many consecutive days, the form of the daily geomagnetic variation with daily patterns of large-scale air circulation in the upper atmosphere.

In figure 1 the monthly average values of the range of the daily variation of the declination for the 11 years 1948-1958 are shown for the five international quiet days² for the three observatories of Honolulu, Tucson, and San Juan. As the range, the difference between the most easterly forenoon hourly value and the most westerly afternoon hourly value of the daily oscillation was used, taking these values from the row for the mean of the five quiet days in the table of hourly values for the particular month in the corresponding yearbook for the respective observatory issued by the U.S. Coast and Geodetic Survey.

To illustrate the prominent asymmetries it was not felt necessary to correct for non-cyclic change, except in the case of Honolulu, where the afternoon westerly extreme value comes at about the end of the Greenwich day. In this case, approximate correction for non-cyclic change was made.

In figure 1 two conspicuous asymmetries are stressed. The range is greater in summer than in winter but it clearly does not follow in a simple way the change of the intensity of solar radiation, because the maximum range shown in the figure comes well after the June solstice, in August, and following the December solstice a smaller maximum, shown at all three observatories, occurs in January. The low value of February is comparable to that of December.

In figure 2 the 11 yearly contributions to each of the three curves of figure 1 are given (on a smaller scale)

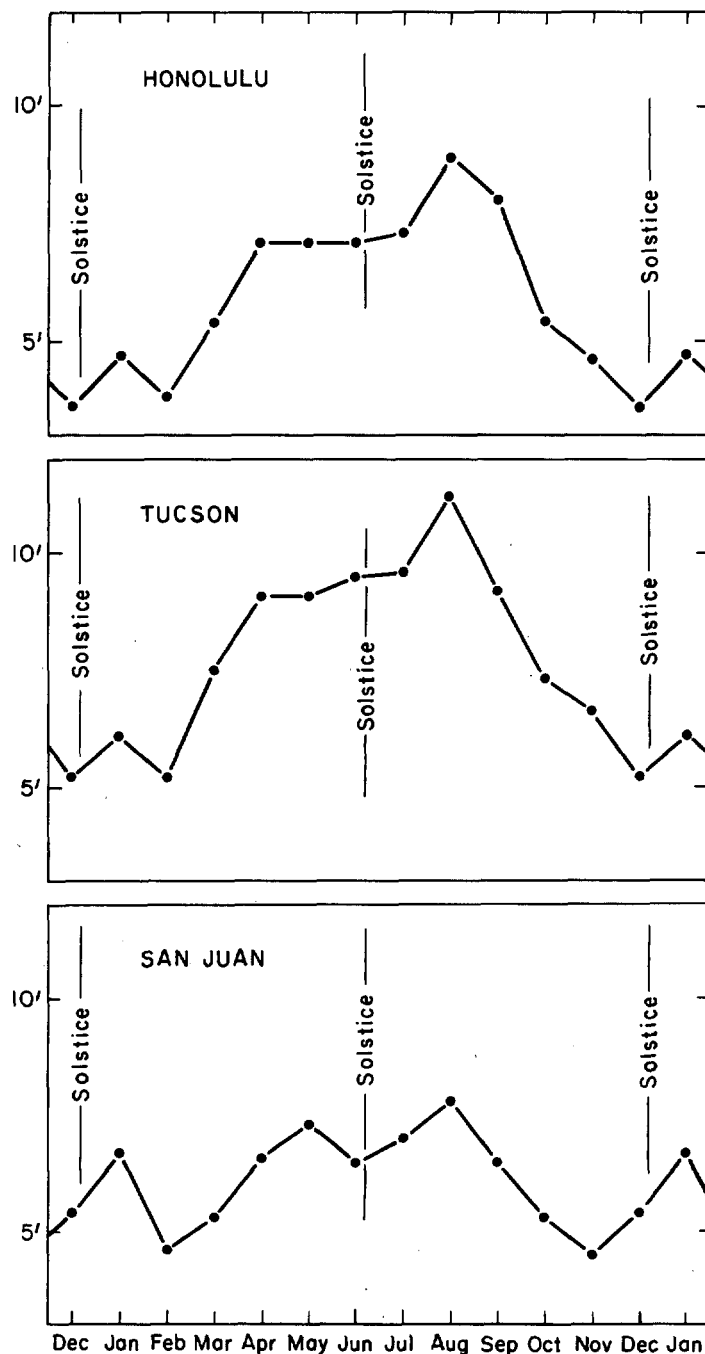


FIGURE 1.—Illustrating the seasonal asymmetry with respect to the solstices, that is, asymmetry with respect to the intensity of ionizing solar radiation in the lower ionosphere, of the range of the daily variation of the geomagnetic declination (the most easterly forenoon hourly value minus the most westerly afternoon hourly value of the daily oscillation, in minutes of arc) at the three indicated observatories. Monthly means, five quiet days, for the 11 years 1948-1958. Note the lag with respect to the summer solstice of the maximum of range in August, and the secondary maximum in January following the winter solstice, with a low value in February comparable to that in December. In this figure December and January, and hence the December solstice, have been repeated to aid in making clear the asymmetric behavior of the declination at this time of year.

² Rather than all days of the month, as used in figure 8 of Wulf and Hodge [5] mentioned above.

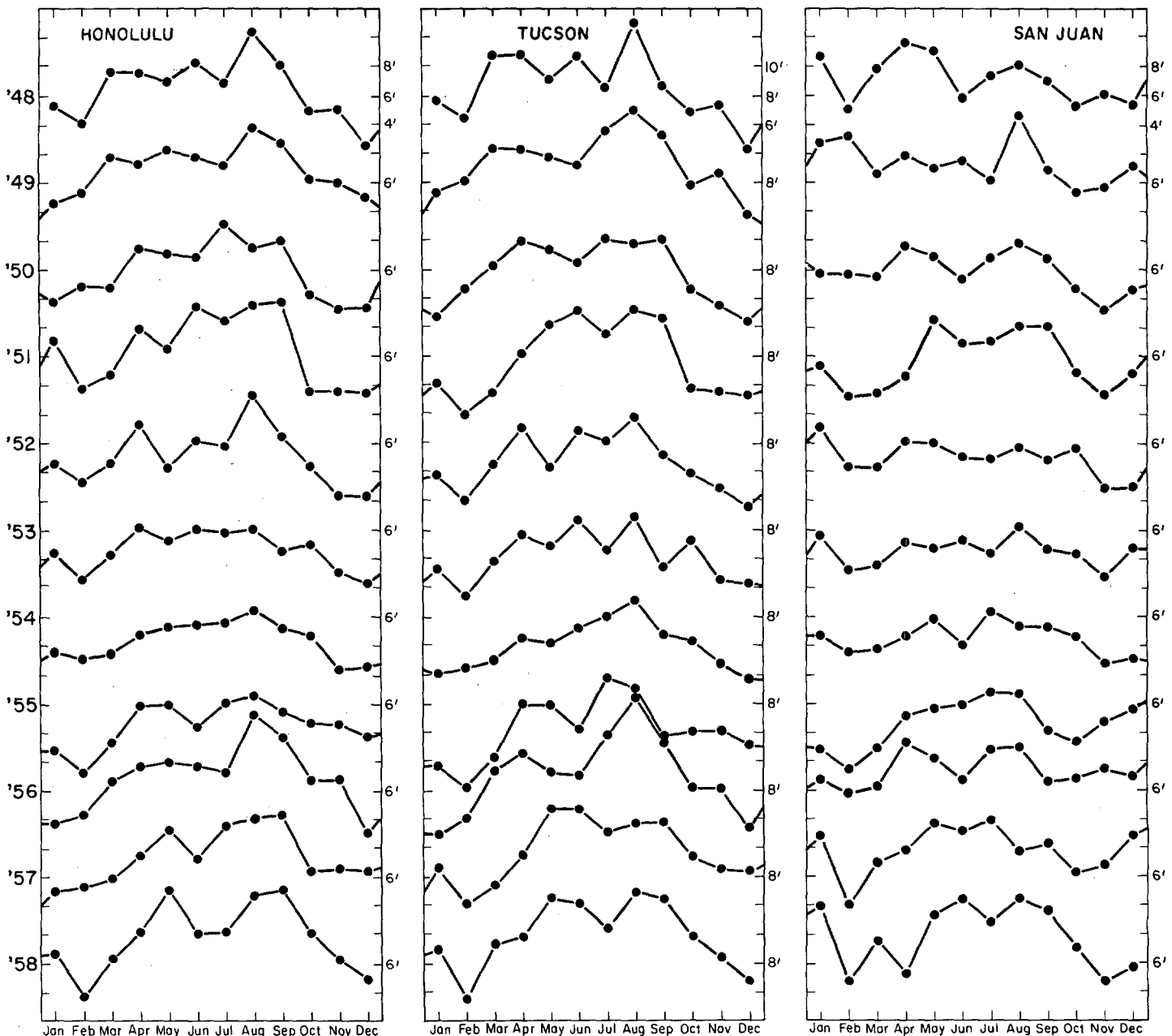


FIGURE 2.—The range of the daily variation of the geomagnetic declination (the most easterly forenoon hourly value minus the most westerly afternoon hourly value in minutes of arc) at the three indicated observatories; five quiet days, 1948–1958. The 11 yearly contributions to figure 1 (on a smaller scale and without the repetition of December and January), given to afford an appraisal of the degree to which the data that yield the averages of figure 1 concur in showing the asymmetry.

mainly to permit an appraisal of the degree of accord which the individual years showed with respect to their averages. There may be other features of interest in addition to the seasonal asymmetry pointed out here.³ Change during the sunspot cycle (minimum in 1954) is evident. Only the asymmetry with respect to the solstices is being stressed at present.

³ It may be recalled that the sun is overhead at noon twice at San Juan, once near the middle of May and again about the end of July.

While the forenoon and afternoon extreme values were being taken from the tables, the hours at which these occurred were also noted. This permits looking, in a rough way, also at the seasonal variation of these times, and it seemed of interest to illustrate the seasonal behavior of the 11-yr. averages. This is done in figure 3, where in each case the average time for the forenoon extreme is given above that for the afternoon. The times of occurrence shown depend somewhat, of course, upon the time

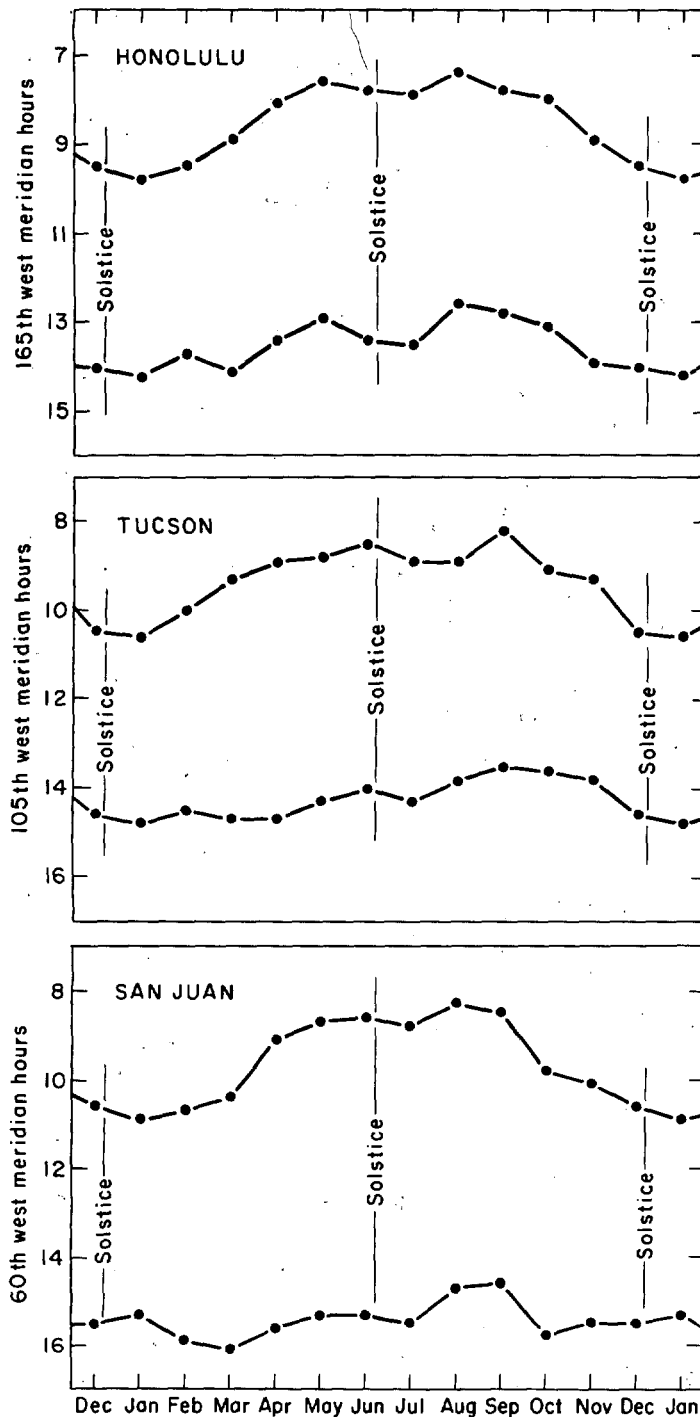


FIGURE 3.—Monthly averages for the 11 years 1948–1958 of the approximate times of occurrence of the most easterly forenoon hourly value (upper curve) and of the most westerly afternoon hourly value in the daily variation of declination at the three indicated observatories; five quiet days.

meridian used by the observatory and upon the observatory's longitude, and no point is made here concerning these times of day. But these times show a seasonal change, and in this seasonal change behavior unsymmetrical with respect to the solstices can also be seen.

Thus the daily variation of the earth's magnetic field at these three observatories shows pronounced unsymmetrical seasonal behavior with respect to the solstices, suggesting the action of an atmospheric factor. This factor is probably the large-scale air circulation in the lower ionosphere involved in the dynamo action leading to the daily variation, as discussed in some detail earlier [3].

Therefore I believe one may conclude that major changes in what is probably the large-scale air circulation in the lower ionosphere usually occur about August and about January–February. But these are just about the times when two major circulatory changes are found in the upper stratosphere [1], as at the 10-mb. surface at about 30 km.; namely, the beginning of the giving way of the dominant summer stratospheric easterlies, and the abrupt change in the winter stratospheric circulation, which is associated at times with remarkably rapid rises in stratospheric temperatures.

3. CONCLUSION

Without any implication that the air circulation is similar in the lower ionosphere and in the upper stratosphere, it does seem probable that major seasonal changes in the two circulations occur at about the same time. A well established interrelation could be of help in understanding large-scale air movement in the mesosphere and lower thermosphere, and this suggests that it would be of much value to make daily comparison of the form of the geomagnetic daily variation with the patterns of large-scale air circulation in the upper stratosphere.

The large-scale circulation in the upper stratosphere as portrayed on a synoptic chart is a detailed but very complex representation of the circulation there at the time. For use in a study of the kind just suggested a greatly condensed representation of the circulation in the form of a daily numerical index, that, though condensed, retained, nevertheless, some significant features, would be extremely helpful. Construction of such an index, applied to charts of the 10-mb. surface, is the subject of the following article.

ACKNOWLEDGMENT

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REFERENCES

1. S. Teweles, L. Rothenberg, and F. G. Finger, "The Circulation at the 10-Millibar Constant Pressure Surface over North America and Adjacent Ocean Areas, July 1957 through June 1958," *Monthly Weather Review*, vol. 88, No. 4, Apr. 1960, pp. 137-150.
2. O. R. Wulf, "A Possible Effect of Atmospheric Circulation in the Daily Variation of the Earth's Magnetic Field," *Monthly Weather Review*, vol. 91, Nos. 10-12, Oct.-Dec. 1963, pp. 520-526.
3. O. R. Wulf, "A Possible Effect of Atmospheric Circulation in the Daily Variation of the Earth's Magnetic Field. II," *Monthly Weather Review*, vol. 93, No. 3, Mar. 1965, pp. 127-132.
4. O. R. Wulf, "On Winds in the Lower Ionosphere and Variations of the Earth's Magnetic Field," *Monthly Weather Review*, vol. 93, No. 11, Nov. 1965, pp. 655-661.
5. O. R. Wulf and M. W. Hodge, "On the Relation between Variations of the Earth's Magnetic Field and Variations of the Large-Scale Atmospheric Circulation," *Journal of Geophysical Research*, vol. 55, No. 1, Mar. 1950, pp. 1-20.

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